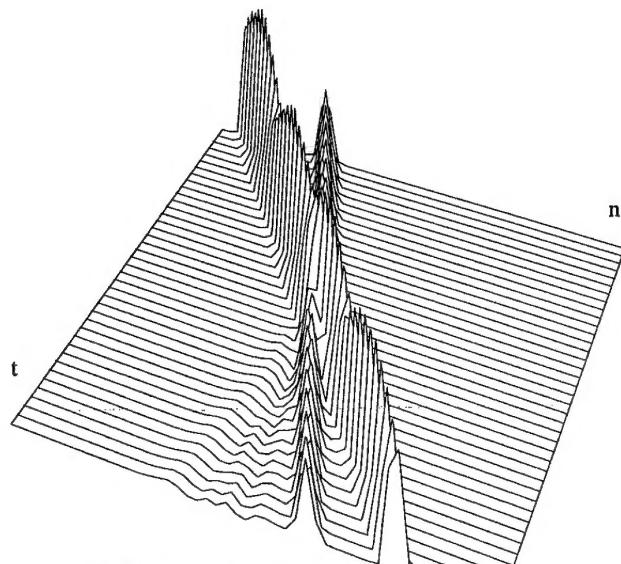




Heriot-Watt University
Edinburgh

Conference on
**Nonlinear Coherent Structures
in Physics and Biology**



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July 10-14 1995

Department of Mathematics
Heriot-Watt University
Edinburgh, Scotland

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1 Introduction

Welcome to Heriot-Watt University and the City of Edinburgh. We hope your stay will be productive and enjoyable. This booklet contains most if not all of the details of the conference, campus, city, but please do not hesitate to ask one of the local organisers for further information if you need it.

Local management of the meeting is by Professor J C Eilbeck and Dr D B Duncan, of the Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, UK, Tel: +44 (0)131 451 3220, Fax: +44 (0)131 451 3249.

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2 Timetable, Talks and Posters

Talks

You have 25 minutes plus 5 minutes for questions. The overall limit of 30 minutes will be strictly adhered to, we have a very tight schedule to keep. The following is a bit obvious, but there are still people who forget it (including me at times!): Please do not try to cram a 1hr talk into this time. Concentrate on getting your main message across, you can go over the details with interested parties after the talk. You may assume that there will be extensive blackboard space available and an overhead projector. Please ask in advance if you need other facilities such as video or slide projection. The lecture theatre seats 140 persons, so those at the back of the room will be a long way from the screen. Please do not attempt to photocopy a normal A4 page onto an overhead slide, this will result in you looking at least half your audience. As a rough guide, the characters on your o/h slides should be at least 7mm high, with 4mm as an absolute minimum (Nature, v.370, 11 Aug 1994).

Posters

The poster area will be in the same area as teas and coffee. If space allows, all the posters will be on show for all the meeting, and no special time will be set aside for poster sessions. You will need to seek out authors to talk to them, so it would be useful if everyone could remember to keep their name badges on. The space available will be 122 cm across x 75 cm down (assuming we can put the boards up in portrait mode, otherwise it will be 150 cm across x 61 cm. down).

Monday 10 July, Lecture Theatre 3

09:00-12:00 Registration, 13:00-14:00 Lunch, 15:30-16:00 Tea

- 13:45-14:00 OPENING ADDRESS,
- 14:00-14:30 Jerry MOLONEY, *Issues relating to the arrest of critical collapse of femtosecond pulses in normally dispersive self-focusing media*
- 14:30-15:00 Sergei TURITSYN, *Stability of optical solitons*
- 15:00-15:30 S Athanasios (Thanasis) FOKAS, *Asymptotics and integrability*
- 16:00-16:30 Vladimir E. ZAKHAROV, *Nonlinear theory of parametric instability in defocusing media*
- 16:30-17:00 Michel REMOISSENTE, *Modulational instability in real systems*
- 17:00-17:30 Peter L. CHRISTIANSEN, *Blow-up and thermal fluctuations in the nonlinear Schrödinger equations*

Tuesday 11 July, Lecture Theatre 3

10:30-11:00 Coffee, 13:00-14:00 Lunch, 15:30-16:00 Tea

- 9:00-9:30 Mark ALBER, *New types of soliton solutions for nonlinear equations*
- 9:30-10:00 Roberto CAMASSA, *New completely integrable evolution equations*
- 10:00-10:30 Allan FORDY, *A new integrable class of coupled NLS equations and related Garnier systems*
- 11:00-11:30 Peter CLARKSON, *Symmetry reductions and exact solutions of shallow water wave equations*
- 11:30-12:00 Maria GANDARAS, *Some symmetries of a nonlinear diffusion equation with absorption*
- 12:00-12:30 Antonio DEGASPERIS, *Perturbation theory and integrability*
- 12:30-13:00 Michele BARTUCCELLI, *Length scales in solutions of a generalized diffusion model in population dynamics*
- 14:00-14:30 Yuri GAIIDEE, *Nonlinear excitations in two-dimensional molecular structures with impurities*
- 14:30-15:00 Dietrich BONART, *Intrinsic localized anharmonic modes at crystal surfaces and edges*
- 15:00-15:30 Alexander EREMKO, *Electromagnetic absorption by molecular solitons*
- 16:00-16:30 Michel PLANAT, *Frequency stability enhancement measured in a soliton-locked type regime of a surface acoustic wave delay*
- 16:30-17:00 Alexander S. KOVALEV, *Exotic solitons in magnetically ordered media*
- 17:00-17:30 Yury A. KOSEVICH, *Exact solution of nonlinear lattice model for surface dynamics and reconstructions*
- 17:30-18:00 Sergey DARMANYAN, *Modulation instability and coherent structure formation in anharmonic lattices*

Wednesday 12 July, Lecture Theatre 3

- 10:30-11:00 Coffee, 13:00-14:00 Lunch, 15:30-16:00 Tea
- 9:00-9:30 Shozo TAKENO, *A lattice Green's function theory and a band-theoretic concept of nonlinear localized modes and envelope*
- 9:30-10:00 Alexander SAVIN, *Topological soliton supersonic states*
- 10:00-10:30 Lisa BERNSTEIN, *Nonlinear Klein-Gordon lattices*
- 11:00-11:30 Alexander ZOLOTARYUK, *Nonlinear proton dynamics in hydrogen-bonded networks*

11:30-12:00 (Francis) Michael RUSSELL, <i>Evidence for energetic anharmonic excitations and applications</i>	17:00-17:30 John M DIXON, <i>A nonlinear field theoretical determination of the one-electron energies of a neutral zinc atom</i>
12:00-12:30 Alexander M. SAMSONOV, <i>How to predict, generate and observe strain solitons in solids</i>	17:30-18:00 Fatkhulla ABDULLAEV, <i>Stochastic instability of chirped optical solitons in media with periodic amplification</i>
12:30-13:00 Vladimir KONOTOP, <i>Coupled solitons in lattices</i>	
14:00-15:30 Canal Event - bus leaves main door at 2pm prompt!	
16:00-16:30 Boris A. MALOMED, <i>Variational approach to the self-trapping equation</i>	9:00-9:30 Silvana DE LILLO, <i>NLS solitons under stochastic forcing</i>
16:30-17:00 Arnold M. KOSEVICH, <i>Soliton solution of a nonlocal sine-Gordon model</i>	9:30-10:00 George TSIRONIS, <i>Breather-like impurity states in nonlinear disordered lattices</i>
17:00-17:30 Yuri S. KIVSHAR, <i>Solutions due to second harmonic generation</i>	10:00-10:30 Larissa BRIZHIK, <i>Stationary soliton states obeying two-component nonlinear Schrödinger equations</i>
19:30-21:0 Wine reception and presentation of the Pnevmatikos award	11:00-11:30 Oksana CHUBYKALO, <i>The Frenkel-Kontorova model with a transfer- sol. degree of freedom</i>
	11:30-12:00 Thomas PESCHEL, <i>Two-dimensional solitary waves in arrays of non- linear waveguides</i>
	12:00-12:30 Leonor CRUZEIRO-HANSSON, <i>The Davydov model - lessons from dimers and N-mers</i>
	12:30-13:00 Vasudev M (Nitant) KENKRE, <i>Studies of the microscopic validity of the discrete nonlinear Schrödinger equation</i>
	14:00-14:30 Mohammad-Hadi FARAHI, <i>Optimal control of the wave equations</i>
	14:30-15:00 Andrew PICKERING, <i>The singular manifold method revisited</i>
	15:00-15:30 Victor Z ENOLSKII, <i>Abelian Bloch solutions of the multidimensional Lamé equation</i>
	16:00-16:30 Martin KRUSKAL, <i>Exponentials in the Painlevé test</i>
	16:30-17:00 Andrew C. HICKS, <i>Approximations to large amplitude solitary waves on nonlinear electrical lattices</i>
	17:00-17:30 Sergej FLACH, <i>Existence and properties of discrete breathers</i>

Friday 14 July, Lecture Theatre 3

10:30-11:00 Coffee, 13:00-14:00 Lunch, 15:30-16:00 Tea	
	9:00-9:30 Silvana DE LILLO, <i>NLS solitons under stochastic forcing</i>
	9:30-10:00 George TSIRONIS, <i>Breather-like impurity states in nonlinear disordered lattices</i>
	10:00-10:30 Larissa BRIZHIK, <i>Stationary soliton states obeying two-component nonlinear Schrödinger equations</i>
	11:00-11:30 Oksana CHUBYKALO, <i>The Frenkel-Kontorova model with a transfer- sol. degree of freedom</i>
	11:30-12:00 Thomas PESCHEL, <i>Two-dimensional solitary waves in arrays of non- linear waveguides</i>
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	16:30-17:00 Andrew C. HICKS, <i>Approximations to large amplitude solitary waves on nonlinear electrical lattices</i>
	17:00-17:30 Sergej FLACH, <i>Existence and properties of discrete breathers</i>

List of Posters

G. Biondini, *Analytical and numerical solutions of the semilinear Burgers equation*

R.K. Bullough, *Solitons and the Korteweg-de Vries Equation: integrable systems 1834-1895*

D. Hennig, *Spatial properties of integrable and nonintegrable discrete nonlinear Schrödinger equations*

R. Hüb, *Combined envelope-envelope solutions on square lattices*

Manuel Manas, *The 2D Dirac Equation and the Davey-Stewartson I Equation: Deformation of the dromion solutions*

José L. Marín, *Breathers in Hamiltonian Lattices: Studies based on the anti-integrability concept.*

V. Marinakis, *On the Integrability of a New Class of Water Wave Equations*

P. Marquié, *Modulational Instability in Discrete Systems*

N. Martucciello, *Static fluxons on periodic structures*

E. John Parkes, *Solitary ion acoustic waves in a plasma with negative ions and non-isothermal electrons*

U. Peschel, *Collisions of Solitary Waves due to Second Order Nonlinearities*

T. J. Priestley, *On a shallow water wave system*

Kim O. Rasmussen, *Non-local Nonlinear Schrödinger Equation*

Iain Skinner, *Coupled coherent nonlinear optical systems*

Shozo Takeno, *A new type of topological localized mode: the rotating mode*

Beata Trpisova, *Kink like soliton propagation in microtubule protofilaments*

Y. Zolotaryuk, *Envelope solitons in a system of magnetic pendulums*

3 Further Information

3.1 Conference Details

- General. There will be an information/registration desk in the area outside lecture theatres 2 and 3 in the main building throughout the conference. Please register on Monday morning if you can.
- **Lunch and Dinner.** Lunch is included in the daily charges for residents and non-residents, but dinner is not. Tickets are required for lunch — collect them at conference registration on Monday morning.
- **Canal visit.** There will be a trip to the canal on Wednesday afternoon to attempt to recreate one of Scott-Russell's original solitons and to name a (relatively) new aqueduct after him.
- **Pnevmatikos Prize Ceremony & Wine Reception.** This will be held on Wednesday evening in the Students Union Building near the loch.
- **Payment of conference and residency fees.** Please pay in cash, or by eurocheque, or by a cheque drawn on a British bank. You can obtain cash from the bank on the campus in a variety of ways (see below). Unfortunately we're not able to accept payment directly using credit cards, you will have to use the bank to get cash from these and pay the cash to us.
- **Communications.** We have arranged a telnet facility so that you can read your home e-mail in the normal way. This will be in the CALM PC Lab on the ground floor of the Mathematics Department. You will need to know the address of your home system to do this of course.

For paper based mail, use the departmental address:

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Fax: +44 (0)131 451 3249
Emergencies: Control Janitors +44 (0)131 451 3500

A plea

We hope you have a pleasant and productive stay here, and the local organisers will do all they can to make it so. But please bear in mind that even small requests can add up to a considerable burden when this is multiplied by 80 participants. The organisers are only human and would like time to attend at least some of the talks and talk to participants about scientific matters. Any problems with accommodation should be directed to the main University reception desk in the first instance. Try to direct all reasonable general enquiries to the secretaries on duty in the first instance. If we get tetchy towards the end of the week please forgive us, if you've organised a meeting yourself you'll know what it's like, if you haven't, you'll never believe some of the things you get asked!

3.2 Campus Facilities

The main cafeteria in the University closes at 1900 each day (including weekends). After 1900 it is possible to get a selection of pub food from the Lectern Pub (situated on the ground floor of the Hugh Nisbet Building, opening hours evenings 17:00-23:00 Mon-Sat, 18:30-23:00 Sun.) There are several bars on the campus, and a number of pubs within 30mins walking distance (the best is probably the Riccarton Arms, ask for directions).

There is a small student shop on the campus selling food, newspapers, stamps, phone cards, etc. There is a book shop (Thins) with good connections to larger book shops in the city (books are tax free in the UK and often cheaper than elsewhere in Europe). If the book you want is in the city centre branch, it can be delivered to the campus the next day. There is a bank (see below), a hairdresser, a laundrette, and a medical centre, including dental facilities.

We have a good sports centre with facilities for jogging, weight training, badminton, squash, table tennis, tennis, and croquet (but no swimming pool).

The University gardens include a 18th century sunken lawn and many fine trees. The Pentland hills 2km south of the campus offer extensive walking facilities.

Banking

The Royal Bank of Scotland has a branch on the campus adjacent to the lecture theatres. This is open Mon-Fri, 9:30-11:30 and 12:30-15:30. You will be able to obtain cash from Visa and Master Card cards, providing you have your passport or identity card with you. There is no charge at this end for this facility, but your credit card company will apply the usual charges for this. You can cash travellers cheques here, there will be no charge if the cheques are in sterling. You can also cash eurocheques, up to 100 pounds per cheque, up to three cheques per day. In some cases the bank can cash personal cheques written in a foreign currency, but the charges for this are higher, and not all cheques can be processed this way.

There is also a cash dispenser open 24hrs which will take cash cards from many banks and also Visa and Master Card cards. For these you will need your 4 digit PIN number, if you have an alphabetical PIN the bank will be able to give you instructions how to translate it into a numerical one.

University (no)smoking policy

Smoking is not allowed anywhere inside the University except in designated areas. The nearest designated area to the lecture theatres and coffee area is 50m away, or you can go outside. Smoking is permitted in bar areas. Smoking is also permitted in bedrooms, though not of course if you are sharing a room with a non-smoker. **We advise you not to smoke in the bedrooms because the fire alarms are extremely sensitive.**

3.3 The City of Edinburgh: transport, bars, restaurants

You should certainly take the chance to see Edinburgh during your visit (though not of course during the conference hours!). It is one of the most beautiful cities in Europe, and if the sun is shining it will be light in July until well after 9pm. The map you will be given on arrival will list the usual tourist attractions, and we have a brief restaurant and pub guide below.

Climate

Daytime temperatures in Edinburgh in July can vary between 12°C and 30°C, though not usually in the same day! Winds can be nonexistent or heavy, precipitation likewise. Be prepared for any situation, you will almost certainly need waterproofs and sweaters at some stage.

How to get there and how to get back

The journey from the campus to the town centre varies between 25 and 35 minutes and most buses require an exact fare of between 70p and 90p. Keep your ticket for random inspections. On weekdays buses go every half hour, but the frequency is reduced in the evenings after 19:00. There are regular buses back to the campus until 23:38, and then a night bus service operates (see later). To confuse the matter, some of the services only run during the daytime on weekdays (no. 65 and no. 45), and some run in the evenings and at weekends (no. 22 and 22A). Full timetables are available on the notice boards near the James Watt Centre reception desk.

To get into town buses leave the campus (James Watt Centre) at the following times on Monday to Friday: 07:32 and every 30 minutes until 19:02, 19:13 and every 30 minutes until 23:13. On Saturday: 7:02 and every 30 minutes until 18:02, 18:20, 18:45, 19:13 and every 30 minutes until 23:13. On Sunday: 8:25,

9:13 and every 30 minutes until 22:43. Ask for "Princes Street" (or "Haymarket" if you are going there).

Returning from town ask for "Riccarton Campus". Lothian Region bus routes 45 and 65 from the city centre run every 30 minutes **during weekdays** and terminate at the James Watt Centre on the campus. The 65 is the quickest and most convenient bus from the centre of Edinburgh and Haymarket stations. Mondays-Fridays, it passes through St Andrew's Square (near the bus station) at 06:44, 07:04, then hh:28 and hh:58, where $7 \leq hh \leq 17$, then 18:28, 18:40, 19:05, 19:24, 19:45, 20:45. It goes along the garden side of Princes Street (just west of Waverley Station) and then to Dalry Road near Haymarket station approximately 10 minutes later than the St Andrew's Square times.

In the evening and at the weekend, the 22 or 22A is the bus you need to get back to the campus. **Weekday evenings** there are 22A buses at hh:08 and hh:38 from St Andrew's square, where $19 \leq hh \leq 23$, stopping on Princes St (a different stop from the 65) and at Haymarket (same as 65). On Saturday take the 22 bus at 07:33, then approx every 30 mins at hh:00 and hh:30, last bus 23:38. (note after 18:33 it becomes the 22A again). On Sunday take the 22A at 08:28, 09:30, 10:08, 10:38, hh:08, 11 $\leq hh \leq 23$. (All times from St Andrew's Square, Princes street, about 2 minutes later, Haymarket approx 10 mins later). **Late busses** are also available, no. 101 (Fri and Sat) 00:15, 01:15, 02:15, 03:15, no. 201 (Sun to Thurs) 12:15, 01:15, 02:15, 04:15. (fixed price $\approx £1.20$) These leave from Waverley bridge (near the main railway station) and stop at Princes St. **A taxi** from the City Centre costs about £12, normal tipping rates in the UK is 10%.

Shopping

All the usual shops (stores if you are from North America) are available around Princes Street, and there are some "Scotish" tartan and woolen goods shops there and on the Royal Mile (High Street) down from the castle. If you are interested in buying unusual whisky or other drinks, Oddbins on Queensferry Street near the junction of Princes Street and Lothian Road, has a good selection and the staff are usually able to give good advice. Most places are open late on Thursday evening and the main bookshop Thins is open late every night (check with the branch on the campus for details).

- Grassmarket: variety of restaurants and bars, interesting area

- Princes Street area: many restaurants and bars up side streets to the North of Princes Street, nice views of castle

- High Street (Royal Mile): many bars & some restaurants, very interesting

Eating

Expect to pay a minimum of £10 per head, not including wine, for any half-decent meal in Edinburgh, unless you visit a chain pizza or burger restaurant. For table service a tip of 10% is reasonable, but check the bill first to see if it has already been added in.

Drinking

Beer could cost you anything from £1.60 to £2.00 per pint and standard measures of spirits are cheaper than that. It is not usual to tip bar staff. Prices must be displayed in bars so you can check first. Bars often open until 23:30 or 24:30 on weekdays and some might be open beyond that at weekends. To stay out even later you should find a nightclub. It is said that the only time there is not some kind of bar open is between 4am and 6am.

Most bars have a reasonable selection of whisky and the local breweries in Edinburgh make McEwan's 80 and Caledonian 80 (dark beers), which are worth a try. (Special and Export are probably best avoided.) There are many smaller breweries scattered around Scotland and various bars sell their beers (as well as English beers) and display "menus" of what they have available. If you drink light beer (lager) the Edinburgh breweries (Tennents and McEwan's) make that too.

A selection of restaurants

- Henderson's, 94 Hanover St. (basement) (225 2131) Long established vegetarian self-service restaurant and wine bar, about 10 pounds per head, often with live piano or other music. Has reasonable beer as well. A good place for a moderate sized group.

- Bamboo Garden: Frederick Street, Chinese

- Bar Roma: 39a Queensferry Road.

- Bar Italia: Lothian Road, Italian.

- Pierre Victoire, Grassmarket (2 locations), good value, French.

- Le Sept, Old Fishmarket Close, French. (Bon rapport qualite/prix et acueil sympathique).

Restaurant and Pub Guide

There are a great number of establishments in Edinburgh, we can't cover all of them. The opinions in this section reflect the personal taste of individual members of staff and are not meant to represent any official views of the University or the Department. The main areas of interest for eating, drinking and exploring are:

- Haymarket: good Indian restaurants, some bars, not much to see

- Stac Polly: Grindlay Street and Dublin Street - price 20 to 30 pounds per head, top quality Scottish restaurant with local produce.
- Howies: 63 Dalry Rd./75 St. Leonards St. - Scottish/French, not as good as Stac Polly but still good value.
- Doric Tavern in Market Street. It looks a bit unsalubrious from the outside, but the food is good, if a little pricey (20 - 25 pounds per head)
- The Verandah and the Monsoon, Indian restaurants in Dalry Road, close to Haymarket and the 65/22 bus stop for HW. Around 10-15 pounds per head. Cavalry Club, West Maitland St (between Haymarket and Shandwick place).
- Kalpna: Clerk Street and 2/3 St Patrick's Square (667 9890), Indian vegetarian.
- Himalaya, 171 Bruntsfield Pl, 229 8216 and Bombay Bicycle Club, 6 Brougham Pl, 229 3839 (both Indian)
- Il Giardino's D'Italia, 158 Bruntsfield Pl, 229 3325 (Sicilian)
- Buntoms, 9 Nelson St, 557 8212 Bangkok, 176 Rose St. (both Thai)
- The Marrakech Restaurant, 30 London Street 556 7293 (Morrocan) (take your own wine - book first)
- Malmaison: 1 Tower Place, Leith (around the corner from The Shore) - inexpensive but stylish French brasserie.
- La Bonne Vie: Causewayside - cosy restaurant serving French provincial cuisine.
- Raj: 89 Henderson St. Leith - Indian restaurant with nice spacious decor overlooking Water of Leith.
- The Bridge Inn, Ratho. 333 1320. A few miles west of the campus with no easy public transport, good Scottish food on the banks of the Union Canal, also canal restaurant barges. About 20-25 pounds per head. Booking recommended.

A selection of pubs

- Kay's Bar, Jamaica St., (off India St, opposite James Clark Maxwell's birthplace at no 14). Small and busy New Town watering hole, good choice of malts.

4 Abstracts of Talks and Posters

The abstracts are listed below in alphabetical order, indexed by the person presenting the lecture or poster.

STOCHASTIC INSTABILITY OF CHIRPED OPTICAL SOLITONS IN MEDIA WITH PERIODIC AMPLIFICATION

Fatkulla Abdullaev (Tashkent)

The chirped optical solitons propagation in the media with periodic amplification is considered. The process is described by application of the variational approach. The nonlinear resonances and chaotic oscillations of pulse width at propagation are studied. The stochastic instability in soliton evolution and stochastic decay of soliton under periodic amplification are predicted. The soliton decay length is found.

NEW TYPES OF SOLITON SOLUTIONS FOR NONLINEAR EQUATIONS

Mark Alber (University of Notre Dame, USA)

In this talk we describe a new class of soliton solutions, called umbilic solitons, for certain nonlinear integrable PDE's. These umbilic solitons have the property that as the space variable x tends to infinity, the solution tends to a periodic wave, and as x tends to minus infinity, it tends to a phase shifted wave of the same shape. The equations admitting solutions in this new class include the Dym equation and equations in its hierarchy. We look for classes of solutions by constructing associated finite dimensional integrable Hamiltonian systems on Riemann surfaces. In particular, in this setting we use geodesics on n -dimensional quadrics to find the spatial, or x -flow, which, together with the commuting t -flow given by the equation itself, defines new classes of solutions. Amongst these geodesics, particularly interesting ones are the umbilic geodesics, which then generate the class of umbilic soliton solutions. This same setting also enables us to introduce another class of solutions of Dym like equations, which are related to elliptic and umbilic billiards.

We also introduce a new kind of soliton object for the focusing nonlinear Schrödinger (f)NLS equation which is generated by a collision of two standard optical solitons. One "sees" this part of the solution only in the complexification of the soliton Hamiltonian system. It is common to study classes of solutions of the (f)NLS equation by using a complex phase space and real time t and space x variables; in addition to this, we complexify x and t and show that particular complex direction is associated with the new type of soliton object. Even though this object is realized in the complexification of the system, we show that it has real effects. In particular, these effects manifest themselves in the phase shifts of interacting solitons.

LENGTH SCALES IN SOLUTIONS OF A GENERALIZED DIFFUSION MODEL IN POPULATION DYNAMICS

M. V. Bartuccelli (University of Surrey, UK)

Length scales involved in dissipative partial differential equations are arguably one of the most important dynamical concepts for properly understanding the spatial and temporal patterns of dissipative flows. Here, a set of length scales for the solutions of the generalized Ginzburg-Landau equation (GGLE),

$$u_t = -\alpha \nabla^4 u + \beta \nabla^2 u + \gamma \nabla^2 u^{2q+1} + \lambda u - \delta u^2,$$

on periodic boundary conditions and in various spatial dimensions have been investigated. This model, in the case $q = 1$, was first studied in the context of population dynamics by Cohen and Murray. They proposed the model in an attempt to consider whether spatial structure could be maintained by means of a diffusive mechanism more general than Fickian diffusion.

NONLINEAR KLEIN-GORDON LATTICES

Lisa J. Bernstein (Idaho State University, USA)

Analytical and numerical studies of nonlinear Klein-Gordon (NKG) lattices in the form

$$\frac{d^2\psi_n}{dt^2} + \psi_n = c_0^2(\psi_{n+1} - 2\psi_n + \psi_{n-1}) - \epsilon \frac{dU(\psi_n)}{d\psi_n} \quad (1)$$

are discussed. Specific nonlinear functions $U(\psi_n)$ considered are motivated by the results of spectroscopic experiments on crystalline l-alanine [1]; this experimental data suggests that anharmonic effects in l-alanine crystals may cause vibrational energy localization. Efforts to adapt Whitham's variational method [2] for studies of NKG lattices are discussed. An averaging approach inspired by [2] can be used to generate approximate equations of motion for the slowly-varying parameters in modulated, single-phase, plane-wave-like solutions of Eq. (1); these parameter equations are presented. While this and other work suggests that equations in the relevant class of NKG lattices do support energy-localizing nonlinear wave solutions, the evidence for localization in the same systems at finite temperature is more subtle. Langevin numerical simulations, of Eq.(1) with thermal noise and damping added, are described. A useful perspective on anharmonic effects at finite temperature, the notion of *statistical localization*, is introduced.

[1] A Migliori, P. M. Moxton, A. M. Clogston, E. Zirngiebl and M. Lowe (1988) *Phys. Rev. B* **38** 13464.
 [2] G. B. Whitham (1974) *Linear and Nonlinear Waves*, Wiley, New York, 485ff;

J. C. Luke (1966) *Proc. Roy. Soc. A* **292** 403-412.

ANALYTICAL AND NUMERICAL SOLUTIONS OF THE SEMILINE BURGERS EQUATION (POSTER)

G. Bioldini & S. De Lillo (Perugia)

We consider the semiline Burgers equation with oscillating boundary condition. Analytical solutions are compared to the results coming from different numerical simulations, relative to both integrable and non-integrable discretizations. It is found that, unlike integrable discretizations, non-integrable discretizations fail at high frequencies.

INTRINSIC LOCALIZED ANHARMONIC MODES AT SURFACES AND EDGES

D. Bonart, A. P. Mayer & U. Schröder (Universität Regensburg, Germany)

On the basis of lattice-dynamical models, anharmonic modes have been found at surfaces and edges of three-dimensional crystal lattices. Their associated displacements are not only localized in the direction(s) vertical, but also parallel to the surface or the tip of the edge. The stability of such modes is tested by molecular dynamics. In the search for anharmonic edge modes, realistic models for alkali halide crystals have been applied. The investigations of an adlayer system make use of *ab initio* data for the on-site potential of the adlayer atoms. The influence of thermal fluctuations of high-frequency surface phonons on the propagation of coherent Rayleigh modes due to resonant coupling via anharmonicity is studied within a simplified model.

STATIONARY SOLITON STATES OBEDIING TWO-COMPONENT NONLINEAR SCHRÖDINGER EQUATION

L. S. Brizhik & A. A. Eremko (Ukrainian National Academy of Sciences)

Stationary states of few extra electrons in a deformable chain, described by the Fröhlich Hamiltonian, are investigated within the adiabatic approximation. In the continuum approximation electron wavefunctions are shown to satisfy many-component nonlinear Schrödinger equation

$$\frac{d^2\Psi_i}{dx^2} = \mu_i^2\Psi_i - 2g(\Psi_1^2 + \dots + \Psi_N^2)\Psi_i, \quad i = 1, \dots, N \quad (1)$$

where

$$E_i = -\frac{\hbar^2\mu_i^2}{2m\kappa^2}, \quad i = 1, \dots, N, \quad g = \frac{\chi^2}{2J\kappa} \quad (2)$$

Here χ is the electron-phonon coupling constant, J is the exchange interaction constant, and κ is the elasticity coefficient of the chain. The solution to the many-component NSE is written down in the quadratures. Within the class of autolocalized states the wave functions of two electrons with opposite spins are shown to coincide with the bisoliton wavefunction, while the wavefunction of the triplet state of two electrons and of four electrons which are

bound pairwise into bisolitons, reads as follows

$$\Psi_1 = \sqrt{\frac{\mu_1^2 - \mu_2^2}{g}} \frac{\mu_1 \cosh \phi_1}{S}, \quad \Psi_2 = \sqrt{\frac{\mu_1^2 - \mu_2^2}{g}} \frac{\mu_2 \sinh \phi_1}{S}, \quad (3)$$

where

$$S = \mu_1 \cosh \phi_1 \cosh \phi_2 - \mu_2 \sinh \phi_1 \sinh \phi_2, \quad \phi_1 = \mu_1(x+\lambda), \quad \phi_2 = \mu_2(x-\lambda), \quad (4)$$

with λ being the constant of integration.

It is shown that the lowest state of two extra electrons in a chain corresponds to the singlet bisoliton. In a triplet state there is the repulsion between the two electrons due to which they form the unbound two-soliton state. Two bisolitons in a chain are also repelled from one another and do not form the bound state. The repulsion between bisolitons leads to the formation of a periodic lattice of bisolitons with the distribution period $l = N/N_{bs}$, $N_{bs} = N_e/2$ that corresponds to the many-electron solution of the Peierls-Froehlich problem at zero temperature. It is shown also that the account of nonadiabatic corrections leads to the additional direct interaction between electrons via the phonon field.

The self-consistent deformation potential of the lattice is a reflectionless one. In the case of one extra electron or a singlet state of two electrons which occupy the same level (bisoliton), this potential has a single bound state. Respectively, it has two bound states for two electrons with parallel spins, and in the case of arbitrary number of electrons the corresponding self-consistent deformation potential is a reflectionless single-band potential with one gap which separates the occupied sublevels from the empty ones.

QUANTUM PENDULUMS

R. K. Bullough (UMIST, Manchester, UK) & **J. T. Timonen** (University of Jyväskylä, Finland)

In the course of evaluating the functional integral for the *classical* partition function for the sine-Gordon model, namely

$$Z = \int \mathcal{D}\Pi \mathcal{D}\phi \exp S[\Pi, \phi] ; \quad S[\Pi, \phi] = -\beta H[\Pi, \phi] ;$$

with $\{\Pi, \phi\} = \delta(x - x')$ and $H[\Pi, \phi] = \gamma_0^{-1} \int \left[\frac{1}{2} \gamma_0^2 \Pi^2 + \frac{1}{2} \phi_z^2 + m^2(1 - \cos \phi) \right] dx$ (in which $\gamma_0, \beta \in \mathbf{R} : \gamma_0 > 0$, while $\beta > 0$ is reciprocal temperature and $\mathcal{D}\Pi, \mathcal{D}\phi$ are Wiener measures), we found 'beyond all orders' low temperature strictly asymptotic expansions for $\ln Z$ which are also found to be the iteration of a system of coupled non-linear integral equations. Thus the asymptotic expansions are 'summable' to these coupled integral equations.

In this talk we show how this problem in classical statistical mechanics for a 'very large number' (2²⁰) of degrees of freedom can be converted to the exact

calculation of the ground state energy of the quantum nonlinear pendulum of length ℓ , Lagrangian $L = \frac{1}{2}\dot{\phi}_t^2 - (g\ell^{-1})(1 - \cos \phi)$, and one degree of freedom; g_0 is the acceleration due to gravity. We show how this quantum nonlinear pendulum problem is apparently solved exactly as a system of closed coupled nonlinear integral equations solvable asymptotically by iteration. We speculate on the comparable calculations for the excited state energies of the quantum nonlinear pendulum.

SOLITONS AND THE KORTEWEG-DE VRIES EQUATION: INTEGRABLE SYSTEMS 1834-1895 (POSTER)

R.K. Bullough & P.J. Caudrey (UMIST, Manchester)

We show in one A3 sheet and/or more substantially how the soliton, first reported by J.S. Russell in August 1834, has come to occupy, in 1995, a central position in the theory of 2-dimensional quantum gravity.

NEW COMPLETELY INTEGRABLE EVOLUTION EQUATIONS

Roberto Camassa (Los Alamos)

A new class of completely integrable nonlinear PDE's has recently been derived in the context of shallow water wave motion and front propagation in nematic crystals. The class of solutions of these equations is surprisingly rich, and it includes solutions with loss of smoothness in finite times and weak soliton solutions. By casting these equations in the framework of complex Hamiltonian systems on Riemann surfaces, and using special limiting procedures, one obtains a unifying geometric point of view. In particular, through this approach, an unexpected connection is found between solutions of the PDE's and the classical problem of geodesic flow on the surface of n -dimensional quadrics. Weak solutions of PDE's, which admit discontinuities in the first derivatives, can be associated with the limiting case in which geodesics on quadrics degenerate into elliptic and hyperbolic billiards. Integrability (by quadrature) of the system of odes governing the position and amplitude of the jumps follows naturally from this approach.

BLOW-UP AND THERMAL FLUCTUATIONS IN THE NONLINEAR SCHRÖDINGER EQUATION

Peter L. Christiansen (Lyngby, Denmark)

Recent joint work with Yu. B. Gaididei, O. Bang and K. Oe. Rasmussen on the effect of multiplicative white noise in the two-dimensional nonlinear Schrödinger Equation will be reported. The main result is that blow-up can be prevented by sufficiently strong fluctuations. The possibilities of applying this model to collective excitations of Langmuir-Blodgett Scheibe aggregates are discussed.

THE FRENKEL-KONTOROVA MODEL WITH A TRANSVERSAL DEGREE OF FREEDOM: STRUCTURES OF KINKS FOR A COMPLEX GROUND STATE

Oksana A. Chubykalo (Universidad del País Vasco, Spain) & **Oleg M. Braun** (Ukrainian Academy of Sciences)

We study a generalized Frenkel-Kontorova (FK) model with a transversal degree of freedom. The model describes a chain of atoms with a fixed concentration interacting by long-range repulsive forces. The chain is placed into a "channel", i.e. it is subjected to a two-dimensional substrate potential which is periodic (sinusoidal) in one direction and symmetric (parabolic) in the transversal direction. With increasing of an amplitude of the interatomic repulsion the ground state (GS) of the model undergoes a series of bifurcations. The first bifurcation corresponds to a continuous (second order) transition from the trivial GS (the configuration where atoms are aligned with a line as in the classical FK model) to the zigzag GS. The further dimerization of ground state correspond to discontinuous (first order) transitions and are the so-called "rhomb" and then "double zigzag" configurations. These GSs may be viewed as more and more broad strips cutted out from the 2D hexagonal lattice.

We propose an approach which allows to find the structure of elementary topologically stable excitations (kinks) for a complex GS. The approach is based on the consideration of the complex GS as that consisting of subchains, each characterizing by the trivial structure, so that the kink of the whole system may be considered as constructed of a set of topological excitations (subkinks) of the subchains.

SYMMETRY REDUCTIONS AND EXACT SOLUTIONS OF A SHALLOW WATER WAVE EQUATION

Peter A. Clarkson & Elizabeth L. Mansfield (University of Kent, UK)

In this lecture I shall discuss symmetry reductions and exact solutions of the shallow water wave (SWW) equation

$$u_{xxtt} + \alpha u_x u_{xt} + \beta u_t u_{xx} - u_{xt} - u_{xx} = 0, \quad (1)$$

where α and β are arbitrary, nonzero, constants. which is derivable using the Boussinesq approximation. Two special cases of this equation have been discussed in the literature; the case $\alpha = 2\beta$ by Ablowitz *et al.* [*Stud. Appl. Math.*, **53** (1974) 249] and the case $\alpha = \beta$ by Hirota and Satsuma [*J. Phys. Soc. Japan*, **40** (1976) 611]. Further (1) is known to be solvable by inverse scattering in these two special cases and the Painlevé test suggest that it is not for other choices of the parameters.

A catalogue of classical and nonclassical symmetry reductions and exact solutions of the SWW equation (1) will given. Of particular interest are families of solutions possessing a rich variety of qualitative behaviours in the special case $\alpha = \beta$. For this special case I shall exhibit and illustrate a wide variety of solutions which arise as nonclassical symmetry reduction, all of which look like a two-soliton solution

as $t \rightarrow -\infty$, yet are radically different as $t \rightarrow \infty$. These results have important implications with regard to numerical analysis and suggest that solving (1) with $\alpha = \beta$ numerically could pose some fundamental difficulties: an exponentially small change in the initial data can yield a fundamentally different solution as $t \rightarrow \infty$. How can any numerical scheme in current use cope with such behaviour?

DISCRETENESS EFFECTS AND SOLITON DIFFUSION IN HYDROGEN BONDED CHAINS.

Thierry Crétegy & Michel Peyrard (l'Ecole Normale Supérieure de Lyon, France)

We investigate discreteness effects in the Antonchenko-Davydov-Zolotaryuk model of hydrogen bonded chains, using a collective coordinate description. We explain why this model may be useful, despite its simplicity. The spectrum of the small oscillations around the kink suggests a two-variable description. An iterative method is introduced to obtain an exact value of the Peierls potential for any value of the collective coordinates and an analytical expression of this potential is derived. It allows us to study the dynamics of the kink and to calculate the Peierls frequency to a good accuracy, particularly for very discrete cases for which the standard one-collective-coordinate approach fails. First results in the diffusion of the kink in the thermalized lattice will also be presented: they show that the two-collective coordinates approach is coherent.

THE DAVYDOV SOLITON: LESSONS FROM DIMERS AND N-MERS.

L. Cruzeiro-Hansson (Birkbeck College, London, UK)

The Davydov model describes how energy can be transferred along protein α -helices in the form of a vibration excitation of the peptide groups called amide I. In the Davydov model the amide I vibration interacts with the phonon modes of the α -helix and solitons can form. An important, and still unanswered question is that of the thermal lifetime of the Davydov soliton at biological temperatures. A brief summary of the field will be presented, with particular emphasis on the behaviour of the system at finite temperature. Results from quantum dynamics at finite temperature will be shown.

MODULATION INSTABILITY AND COHERENT STRUCTURE FORMATION IN ANHARMONIC LATTICES

S. Darmyan & V. Burlakov (Institute of Spectroscopy RAS, Moscow)

Normal mode instability in the anharmonic lattices has been investigated both analytically and numerically. Double-band structure of instability region in wave vector space of perturbation waves has been found. A criterion for the long-wave modulation instability of running waves which can be regarded as a generalization of the Lighthill criterion is proposed. The results are discussed in connection with the problem of coherent structure formation in anharmonic lattices.

STABILITY OF PERIODIC ARRAYS OF VORTICES

Thierry Dauxois (Ecole Normale Supérieure de Lyon, France)

The stability of periodic arrays of counter-rotating vortices is discussed. We derive with the energy-Casimir stability method the nonlinear stability of this solution in the inviscid case as a function of the solution parameters and of the domain size. We exhibit the maximum size of the domain for which the vortex street is stable.

By adapting a numerical time-stepping code, we calculate the linear stability of the solution in the presence of viscosity and compensating forcing. Finally, the results are discussed and compared to a recent experiment in fluids performed by Tabeling et al. [Europhysics Letters 3, 459 (1987)]. Electromagnetically driven contra-rotating vortices are unstable above a critical electric current, and give way to co-rotating vortices. The importance of the friction at the bottom of the experimental apparatus is also discussed.

PERTURBATION THEORY AND INTEGRABILITY

A. Degasperis (Università di Roma "La Sapienza" & Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italy)

We consider the effect of weak nonlinearity on the propagation of one-dimensional strongly dispersive waves. In the standard quasi-monochromatic approximation, it is well-known that the first-order amplitude modulation satisfies the Nonlinear Schrödinger equation in "slow variables". We explore the higher order effects, and provide a well-defined procedure to compute all coefficients of the perturbative expansion as bounded functions (no secularity effects) of stretched variables. Key-ingredient is the integrability of the Nonlinear Schrödinger equation and its commuting symmetries.

NLS SOLITONS UNDER STOCHASTIC FORCING

Silvana De Lillo (Perugia)

The NLS equation under stochastic forcing is considered in the case of weakly correlated and strongly correlated noise. The model considered is of applicative interest for the analysis of soliton propagation in optical fibers with a random distribution of inhomogeneities. The statistical average of the soliton solution and some relevant two-point correlation functions are obtained.

A NONLINEAR FIELD THEORETICAL METHOD OF DETERMINING THE ONE-ELECTRON ENERGIES OF A NEUTRAL ZINC ATOM: COMPARISON WITH HARTREE FOCK CALCULATIONS.

John M. Dixon (Warwick, UK)

A field theoretical approach, the Method of Coherent Structures, has been employed to determine the one-electron energies of a neutral zinc atom. Spatial correlations are properly accounted for in this semiclassical approach and the essentially Fermionic character of the electrons emerges via physical boundary

conditions on the choice of classical field. We interpret the classical field as a coherent state envelope which partly determines the effective potential in which quantum fluctuations take place. We find that three distinct regimes of behaviour of the classical field exist depending on the magnitude of the effective Coulomb repulsion, μ . When $\mu < \mu_0$, a critical value, those classical fields which correspond to certain discrete values of μ are physically acceptable normalisable bound charge states. When $\mu < \mu_0$ and does not correspond to the discrete values, classical solutions exhibit a damped oscillatory behaviour typical of charged 'ring' waves. For $\mu > \mu_0$, corresponding to an excess of electronic charge, only a small fraction of the charge, represented by a few oscillations about the nucleus, remains attracted to this centre while the remainder escapes from the nucleus. Parameters representing the repulsive energy strength and energy shifts agree well with trends in the Slater parameter $F^0(2s, 2p)$ as a function of atomic number Z and also Moseley's Law. Agreement is also obtained with the first-principles form of charge density at small distances from the nucleus as given by Kato's Theorem and also at large distances as outlined by March. The usefulness and validity of this approach has been shown by comparing such energies with those determined by a Hartree-Fock-Slater (HF) methods which is well known to satisfactorily account for many specific details of the level structure of atoms. Good agreement with HF has been obtained for both shell positions and energy ordering of states within a shell.

NONLINEAR SCHRÖDINGER EQUATIONS, QUANTUM ALGEBRAS AND PHASE-SPACE GEOMETRY

Demosthenes Ellinas (University of Crete, Greece)

Lattice versions of the nonlinear Schrödinger equation (NLS) such as the discrete NLS (DNLS), the Ablowitz-Ladik (AL) and a hybrid system (AL-DNLS) which interpolates between them are considered in their classical and quantized forms. For f sites, the dynamical algebras of these models is shown to be generated by the $su(f)$ for the quantum DNLS and the quantum algebra $su_q(f)$ for the two others. The classical versions of the models are obtained by introducing their quasiclassical limit, then the dynamical algebras become the $su(f)$ Poisson algebra and the quasiclassical quantum algebra $su_q(f)$. For the case of quantum dimer (QDNLS, $f=2$) a coherent state path integral is developed to determine the time evolution in the WKB limit; the formalism allows to study the relation of self-trapping with quantization. Similarly the two other lattice models are quantized and studied by means of a q -coherent state path integral. Next for both the quantum and the classical forms of the models it is shown that their associated phase spaces have non trivial geometry and are symplectic phase space manifolds with Kähler structure and Riemannian manifolds with non constant curvature due to q -deformation; the interrelation between dynamics, q -deformation and phase space geometry for these systems is further analyzed.

Finally, utilizing the dynamical symmetry of these models given by a quantum algebra with non trivial Hopf algebra structure and its non cocommutative comultiplication, new discretized versions of the NLS are put forward and discussed.

ABELIAN BLOCH FUNCTIONS AND MULTI DIMENSIONAL LAMÉ EQUATION

V Z Enolskii (National Academy of Sciences of Ukraine)

The theory of hyperelliptic σ -functions initiated by Klein can be developed at the same level of the formulae explicitness as the Weierstrass theory of elliptic functions. We give the principal relations of this theory and describe explicitly the Kummer variety whose geometry is naturally connected with the KdV hierarchy. We introduce further the notion of Abelian Bloch, which are the generalization of the Baker-Akhiezer functions on the case of Abelian torus. The addition theorem for Abelian Bloch function is derived as the consequence of the addition theorem for the σ -function. As an application of the apparatus developed we consider multi dimensional Lamé equations which arises as a compatibility condition for the existence of the addition theorems for the Abelian Bloch functions. The special cases of the singular and curve which are the coverings over tori are considered. The application of the Weierstrass-Poincaré reduction theory comes in this case to some new multi dimensional potentials being expressed in terms of elliptic functions.

ELECTROMAGNETIC ABSORPTION BY MOLECULAR SOLITONS

Alexander Eremko (Ukrainian National Academy of Sciences, Kiev)

The strong interaction of quasiparticles with lattice vibrations results in novel features of such systems. This especially concerns the one-dimensional systems where a short-range electron- or exciton-phonon interaction leads to formation of a stable autolocalized state called the Davydov's soliton [1] which can be responsible for the energy and charge transport. Solitons manifest themselves under external forces due to chain imperfections or external fields. The investigation of soliton's interaction with external electromagnetic field allows one to study (i) the dynamical properties and (ii) the inner electron structure of solitons.

In the general case in the presence of external perturbative force, F , in the adiabatic approximation the soliton c.o.m. coordinate R is shown to obey the dynamic equation

$$m\ddot{R}(t) + \int_0^\infty \ddot{R}(t-\tau)K(\tau)d\tau = F(R, t). \quad (1)$$

Here m is the mass of undressed quasiparticle, the kernel K describes retardation effects in the chain deformation accompanying the soliton. In the case of alternating electromagnetic field the retardation effect leads to the characteristic soliton absorption with the maximum at the frequency $\omega_0 = 2\mu V_a/\pi$. Here μ is the inverse width of a soliton, and V_a is the sound velocity in a chain. In this

case the effective dynamic mass of a soliton depends on the field frequency. At small frequencies, $\omega \ll \omega_0$, it coincides with the soliton ("dressed" quasiparticle) mass: $m_d = m + \int_0^\infty K(\tau) d\tau$ [2], while at high frequencies, $\omega \gg \omega_0$, with the mass of a free quasiparticle.

Another type of characteristic electromagnetic absorption by solitons is connected with the quantum electron transitions from a soliton state to a free quasiparticle state (photodissociation) [3], at the frequency $\omega_{diss} = \hbar\mu^2/m$.

[1] A.S.Davydov. Solitons in molecular systems. Reidel Publ. Co., Dordrecht, 1985.

[2] A.S.Davydov, A.A.Eremko. Teor. Mat. Fis., 43, 367 (1980).

[3] A.A.Eremko, in: Davydov's Soliton Revisited, A. C. Scott and P. L. Christiansen eds., Plenum, London, 1990, p. 429.

DESIGN OF "PISTON" FOR LARGE AMPLITUDE SOLITARY WATER WAVE GENERATION

W.A.B. Evans (University of Kent, UK)

From accurate numerical solitary wave profiles, obtained from the solution of an exact integral equation, numerical results for the motion of the fluid along several streamlines as viewed from the laboratory system are obtained via the Gear-Nordström algorithm, for various solitary waves of differing amplitudes, including the maximum wave. The accuracy of the trajectories and motion so deduced is typically 6 sig. figs. or better. A new theoretical aspect of this motion is proven, namely that the *initial* trajectory of a fluid particle (viewed from the Lab system) is inclined at an angle to the horizontal equal to Stokes' decay coefficient, μ , times the ratio of the initial undisturbed height of the particle above the canal bed divided by the undisturbed depth, h , of the canal. From such information the motion and *time-dependent* shape of a sophisticated "Solitary Wave Piston" may be computed. Such a piston would enable the generation of *perfectly-formed* solitary waves of large amplitudes in laboratory tanks of modest lengths.

OPTIMAL CONTROL OF THE WAVE EQUATION

M. H. Farahi (University of Leeds, UK)

We consider the existence and numerical estimation of the distributed control of a nonlinear wave equation with an integral performance criterion and fixed final state. The problem is modified into one consisting of the minimization of a linear form over a set of pairs of positive measures satisfying linear constraints. The minimization in the new problem is global and; it can be approximated by means of the solution of a finite-dimensional linear programming problem. The solution of this problem is used to construct a nearly optimal control. An example is given to illustrate the procedure.

EXISTENCE AND PROPERTIES OF DISCRETE BREathers
Sergej Flach (Max-Planck-Institut für Physik Komplexer Systeme, Dresden, FRG)

Nonlinear classical Hamiltonian lattices exhibit generic solutions in the form of discrete breathers. These solutions are time-periodic and (at least) exponentially localized in space. The lattices exhibit discrete translational symmetry. Discrete breathers are not confined to certain lattice dimensions. Necessary ingredients for their occurrence are the existence of upper bounds on the linear spectrum (of small fluctuations around the groundstate) of the system as well as the nonlinearity. I will present existence proofs, formulate necessary existence conditions, and discuss structural stability of discrete breathers. The following results will be also discussed: the birth of breathers through tangential bifurcation of zone boundary plane waves; details of the spatial decay; numerical methods of obtaining breathers; interaction of breathers with phonons and electrons; applications.

TWO-DIMENSIONAL EFFECTS IN JOSEPHSON JUNCTIONS

N. Flytzanis (University of Crete, Greece), J. G. Caputo (Institut National de Sciences Appliquées, France), Y. Gaitaidei (Institute for Theoretical Physics, Kiev, Ukraine) & E. Varalidis (University of Crete, Greece)

The one dimensional sine-Gordon model with a driving term due to the external current has been successful in describing many of the static and dynamic properties of narrow junctions with overlap boundary conditions. This is reflected in both $I - V$ characteristics and experimental measurements of the maximum tunneling current vs the external magnetic field. In a large area Josephson junction, however, two dimensional effects become important due to the break of symmetry. We developed a hybrid Split Fourier Mode method to study the electromagnetic behavior. The steady-state solution consists of two terms, the first of which satisfies the inline like bias current boundary conditions and has zero fluxon content. The second is treated in a mode expansion in the y -direction and only two terms are sufficient to reproduce the direct solution of the two-dimensional junction for widths up to 2π in units of the Josephson characteristic length. We also introduce the fluxon content along the two directions reflecting the flux for the two normal boundaries. From this approach we give a direct justification to treat the bias current as a driving term for the 1-d model, which is sufficient for widths $w < 2$. For larger widths there can be significant deviations.

ASYMPTOTICS AND INTEGRABILITY

A S Fokas (Loughborough University, UK)

A certain integrable generalization of the KdV equation derived from mathematical consideration in the early 1980's, together with the concept of master symmetries, are used to establish the asymptotic integrability of inviscid, incompressible, irrotational, one-directional, 2D, water waves.

MATRIX NLS EQUATIONS DERIVED FROM COUPLED KdV EQUATIONS

Allan Fordy (University of Leeds, UK)

In this paper we perform a multiple scales analysis on the coupled KdV systems associated with some matrix Schrödinger operators. We derive the corresponding matrix NLS equations, together with their zero-curvature representations. One particular class of these constitutes a new, integrable NLS system. We then consider the stationary flows of these equations and present a new integrable generalisation of the Garnier system, having a $2N \times 2N$ Lax matrix, from which we calculate the constants of motion.

NONLINEAR EXCITATIONS IN TWO DIMENSIONAL MOLECULAR STRUCTURES WITH IMPURITIES

Yu.B. Gaididei (Institute for Theoretical Physics, Ukraine)

We study the nonlinear dynamics of electronic excitations interacting with acoustic phonons in two-dimensional molecular structures with impurities. We show that the problem is reduced to the nonlinear Schrödinger equation with a varying coefficient. The latter represents the influence of the impurity. Transforming the equation to the non inertial frame of reference coupled with the center of mass (c.m.) we can investigate how the c.m. motion influences the internal structure of the solution. Using a parabolic potential with a time varying coefficient to describe the solution behavior in the close vicinity of the impurity we find that in this case the c.m. motion and internal degrees of freedom are separated. With the help of the lens transformation we show that the soliton width is governed by a Ermakov-Pinney equation. We also investigate bound state of the soliton with impurity and show that in addition to the radially symmetric bound state a dipole-like state can exist if the number of excitations in the soliton does not exceed some threshold value. We study both the equilibrium states and the dynamics of the dipole-like excitations. Analytical results are in good agreement with numerical simulations of the nonlinear Schrödinger equation.

SOME SYMMETRIES OF A NONLINEAR DIFFUSION EQUATION WITH ABSORPTION

Maria Luz Gandarias (Universidad de Cadiz, Spain)

The Lie-group formalism is applied to deduce symmetries of the nonlinear diffusion equation with absorption $u_t = (u^n)_{xx} + g(x)u^n$. We study those spatial forms which admit the classical symmetry group. The reduction obtained from the optimal system of subalgebras are derived. Some new exact solutions can be obtained.

REDUCTIONS OF THE BENNEY EQUATIONS (POSTER)

John Gibbons (Imperial College, London, UK)

The Benney equations, an integrable Hamiltonian system of hydrodynamic type, admit many reductions, in which only finitely many of the dynamical variables $A_n(x, t)$ are independent. These reductions satisfy integrability conditions, which

are themselves of hydrodynamic type, but with an inhomogeneous term. Similar constructions are possible for other integrable moment hierarchies, and it is possible to find Miura maps between reductions of the modified and unmodified Benney hierarchies. Many interesting open questions remain, in particular, whether the integrability condition is itself an integrable system.

SPATIAL PROPERTIES OF INTEGRABLE AND NONINTEGRABLE DISCRETE NON-LINEAR SCHRÖDINGER EQUATIONS (POSTER)

D. Hennig (Freie Universität Berlin, Germany)

We study the spatial properties of a nonlinear discrete Schrödinger equation introduced by Cai, Bishop and Gronbech-Jensen (*Phys. Rev. Lett.* **72**, 591 (1994)), that interpolates between the integrable Ablowitz-Ladik equation and the non-integrable discrete nonlinear Schrödinger equation. We focus on the stationary properties of the interpolating equation and analyze the interplay between integrability and nonintegrability by transforming the problem into a dynamical system and investigating its Hamiltonian structure. We find explicit parameter regimes where the corresponding dynamical system has regular trajectories leading to propagating wave solutions. Using the anti-integrable limit we show the existence of breathers. We also investigate the wave transmission problem through a finite segment of the nonlinear lattice and analyze the regimes of regular wave transmission. By analogy of the nonlinear lattice problem with chaotic scattering systems we find the chain lengths at which reliable information transmission via amplitude modulation is possible.

APPROXIMATIONS TO LARGE AMPLITUDE SOLITARY WAVES ON NONLINEAR ELECTRICAL LATTICES

Andrew C. Hicks, Alan K. Common & Mohamed I. Sobhy (University of Kent, UK)

In this paper we describe an approximate method to characterise solitary wave solutions of nonlinear lattice equations. It is based upon one and two point Padé approximations to a series of the real exponential traveling wave solutions of the underlying dispersive system.

The theory is applied to an example of a lattice system which models an experimental nonlinear transmission line and comparison is made with numerical simulations. Furthermore, speed-amplitude relationships are derived for the pulse solutions using quasi-continuum methods. In particular, the method based around Padé approximants yields results consistent with numerical simulations even for relatively large amplitude solitary waves.

COMBINED ENVELOPE-ENVELOPE SOLITONS ON SQUARE LATTICES (POSTER)

R. Hüß (Universität Bayreuth, Germany)

A square lattice with nonlinear interactions between nearest and next-nearest neighbours is considered. These interactions are described by potentials in form

of a series up to fourth order in the relative displacements. In a previous work [1] we demonstrated the existence of a combined state of a pulse and envelope solitary wave for the longitudinal and transversal displacement respectively. These excitations depend solely on one space variable. In this work we extend this approach by looking for structures which depend on both space directions. We consider localization in the longitudinal direction while in the transversal direction a periodic modulation is applied. Numerical simulations indicate the possibility of long-lived excitations of this kind, where both displacement fields are envelope structures along the longitudinal direction. The results of the simulations and some hints for an analytical investigation are presented.

[1] R. Haf, F.G. Mertens and Y. Gaididei. Pulse-envelope solitons on 2-d lattices with in-plane displacements. In A.R. Bishop, S. Jiménez, and L. Vázquez, editors, *Fluctuation Phenomena : Disorder and Nonlinearity*, Singapore. World Scientific. in press.

STUDIES OF THE MICROSCOPIC VALIDITY OF THE DISCRETE NONLINEAR SCHRÖDINGER EQUATION

V M Kenkre (U. New Mexico, USA)

Semiclassical equations of motion such as the discrete nonlinear Schrödinger equation (equivalently, the discrete selftrapping equation) and extensions, have served as a point of departure for a huge amount of analysis of transport in quantum systems, particularly in the context of Davydov solitons [1]. Serious questions regarding their validity have been raised recently, the clearest such study being that of Grigolini and collaborators [2]. Our exact analysis of a simplified system supports some of the conclusions drawn in [2] regarding the questionable status of semiclassical starting points. However, it also results in a precise limit in which the semiclassical starting point is exact [3]. In addition, we find excellent agreement of the exact results with those of the memory approach, an approximation suggested many years ago for the transport of exciton dynamics [4].

[1] See, for example, *Davydov's Soliton Revisited: Self-Trapping of Vibrational Energy in Protein*, eds. P.L. Christiansen and A.C. Scott (Plenum Press, New York, 1990).

[2] D. Vitali, P. Allegrini, and P. Grigolini, *Chem. Phys.* **180**, 287 (1994).

[3] M. Salkola, A.R. Bishop, V.M. Kenkre, and S. Raghavan, *Phys. Rev. B* **52**, August (1995); V.M. Kenkre, S. Raghavan, A.R. Bishop and M. Salkola, UNM-LANL preprint.

[4] V. M. Kenkre, *Phys. Rev. B* **12**, 2150 (1975).

SOLITONS DUE TO SECOND HARMONIC GENERATION

Yuri S. Kivshar (Australian National University, Canberra)

It is shown that mutual phase-matched interaction between the fundamental and second-harmonic waves in a dispersive (or diffractive) medium with quadratic

nonlinearity can support a variety of solitary waves including bright and dark solitons, solitons with trapped radiation, stable bound states of two (or more) dark solitons. Stability of two-wave bright solitons is investigated analytically and numerically. It is found that the solitons can become *unstable* when the phase matching between the fundamental and second harmonics is not exactly satisfied. The analytical criterion for the linear instability is presented, and it is revealed that the nonlinear regime of the instability development leads to two possible scenarios of the soliton dynamics, either large-amplitude in-phase oscillations of two harmonics or the soliton decay. Such amplitude oscillations are explained by the existence of the nontrivial internal mode of the envelope solitons, which can be also found in some other nonlinear models, e.g. those described by the generalized nonlinear Schrödinger equations. The results are demonstrated for parametric interactions in optical $\chi^{(2)}$ materials, where the two-wave solitons have been recently observed experimentally in optical slab waveguides.

COPLED SOLITONS IN LATTICES

Vladimir Konotop (Madeira)

The general theory of small amplitude envelope solitons in one-dimensional lattices with cubic and quartic nonlinearities is developed. It is shown that for large diversity of both linear interactions among the particles and types of nonlinearity the dynamics of chain excitations is governed either by the nonlinear Schrödinger equation or by the system of coupled nonlinear Schrödinger equations. In particular, the theory allows including lattices with long-range interactions and chains with a complex cell in the unique scheme, which is the envelope function approach. The novel classes of solitons in diatomic lattices and in chains with long-range interactions are described as particular examples.

SOLITON SOLUTIONS OF A NON-LOCAL SINE-GORDON MODEL

A.M. Kosevich, A.S. Kovalev, I.M. Babich & B.I. Verkin (Institute for Low Temperature Physics and Engineering, Kharkov, Ukraine)

Starting from the nonlinear equation describing a non-local interaction of dipoles along 1D chain [1] we derive a differential nonlinear equation which is a good approximation for the integral equation in the case of the short-range non-locality. The derived equation coincides with the generalized sine-Gordon equation posed in Ref.[2]. The kink-like analytical solutions of the equation under consideration are known [2]. Using the asymptotic perturbation method we present analytical solutions of the two-parametrical dynamical soliton type and a bound state of kink-like solitons. It is found the solitons can transform into compactons in a special limiting case.

[1] L. Vazquez, W.A.B. Evans, G. Rickayzen, *Phys. Lett.* **A189** (1994) 454.

[2] H. Zorski and E. Infield, *Phys. Rev. Lett.* **68** (1992) 1180.

EXACT SOLUTION OF NONLINEAR LATTICE MODEL FOR SURFACE DYNAMICS AND RECONSTRUCTIONS

Yuriy A. Kosevich (Surface and Vacuum Research Center, Moscow, Russia)

The (100) face of the bcc transition metals such as W and Mo, exhibits an electronically driven reversible surface structural phase transition from a (1×1) symmetry at high temperatures to a lower symmetry phase at lower temperatures [1]. We present an exact solution of effective nonlinear lattice Hamiltonian of crystal surface at $T = 0$, which describes the *anharmonic* intra- and interlayer interactions in the top and subsurface layers. The model accounts also for *intrinsic* surface strain as independent variable, thermodynamically conjugated to surface stress. As it was recently shown, the finite-amplitude sinusoidal plane waves with a short commensurate wavelength and amplitude-dependent frequencies are exact nonlinear eigenmodes of the lattices with similar interatomic anharmonic potential between any arbitrary number of nearest and non-nearest neighbors [2]. Using the ansatz of nonlinear sinusoidal waves, we calculate exactly the spectrum of propagating and static nonlinear sinusoidal surface waves as well as sinusoidal surface lattice solitons in the considered system. Within the framework of the model, surface reconstruction occurs due to the softening of the propagating or spontaneous appearance of one of the static nonlinear sinusoidal surface waves. In both cases it results in the formation of dispersive sinusoidal surface structure with a short commensurate spatial period, rapidly decaying into the bulk lattice. Several commensurate eigenwavenumbers of stable dispersive sinusoidal surface structures, with their amplitudes and phases, are found at the edge and within two-dimensional Brillouin-zone. The corresponding static sinusoidal surface waves are *exact* nonlinear eigenmodes of the system. The transitions are driven by *negative* harmonic surface force constants (on the background of positive bulk force constants), which appear in the model due to effective nonlinear renormalization of bare positive surface force constants by *equilibrium* intrinsic surface strain. Besides the reconstruction on bcc Mo(100) and W(100) surfaces [1], the appearance of sinusoidal dispersive static surface wave with commensurate wavelength in consequence of reversible surface structural transition was experimentally revealed also on free surfaces of ultrathin epitaxial fcc Fe films on Cu(100) [3, 4].

- [1] J. E. Inglesfield, *Prog. Surf. Sci.* **20**, 105 (1985).
- [2] Yu. A. Kosevich, *Phys. Rev. Lett.* **71**, 2058 (1993).
- [3] W. Daum et al., *Phys. Rev. Lett.* **60**, 2741 (1988).
- [4] P. Bayer et al., *Phys. Rev. B* **48**, 17611 (1993).

EXOTIC NONLINEAR EXCITATIONS IN FERROMAGNETS

A.S.Kovalev (Institute for Low Temperature Physics and Engineering, Kharkov, Ukraine)

Recently some attention has been focused on the new type of "exotic" soliton solutions of nonlinear evolution equations - so called "compactions" and "picons".

The field variable in compacton is nil exactly outside the domain of finite length and is proportional to trigonometric function (as in linear system) inside of this domain. In picons the field is proportional to exponential function of modulus of coordinate with definite amplitude. We investigate the new examples of compactons and picons in classical 1D uniaxial ferromagnet with on-site anisotropy and strong anisotropic exchange interaction in the Ising limit and limit of XY -model. In the Ising limit with easy-axis anisotropy there exists both compact domain walls and dynamic compactons with positive and negative frequency. In Ising ferromagnet with easy-plane anisotropy immobile picons exist which are similar to magnetic rotary waves or Lieb states in a nonideal Bose-gas. In classical XY -model there are picon-type domain walls in easy-axis ferromagnets and compacton-type rotary waves in easy-plane case. We show that all these solutions represent the limit of analytical functions and study the envelope solutions, domain walls and rotary waves in the near-Ising and near-XY ferromagnets. The quantum treatment of new type solitons is advanced. It is well known that a small amplitude soliton is a classical analogue of a bound state of bosons in bose-gas with a point two-particle interaction. A soliton in system with saturate nonlinearity is a classical analogue of bound state of bosons in bose-gas with point two-particle attraction and three-body repulsion. Exotic solitons are the classical analogues of a bound state of bosons in bose-gas with two-particle but complicated interaction. We propose the simple model of such interaction with two-body point attraction and repulsion on different distances. This quantum system is completely integrable in terms of Bethe ansatz. In Hartree approximation this quantum model transforms into the nonlinear equations with nonlinear terms involving spatial derivatives. Such equations arise in the theory of nonlinear waves in magnetically ordered and elastic media. The soliton solutions of these equations in some limits have an exotic form.

EXPONENTIALS IN THE PAINLEVÉ TEST

Martin Kruskal

The so-called Painlevé test for the integrability of a mostly analytic polynomial differential equation consists of finding formal solutions as power series of some sort in the hope of determining whether branching (multivaluedness) occurs in some of the solutions. It will be shown that it is sometimes natural and effective to extend this method by including appropriate exponential terms in the representation.

VARIATIONAL APPROACH TO THE SELF-TRAPPING EQUATION

Boris Malomed (Tel Aviv University, Israel) & Michael Weinstein (University of Michigan, USA)

We report preliminary results obtained for solitary pulses in a discrete nonlinear Schrödinger (self-trapping) equation in an infinite domain by means of the variational approximation. We assume a certain ansatz for the pulse, following

the pattern of the variational approximation for pulses in the continuum model. Using the conservation of the "number of quanta" (NOQ), we bring the evolution equations for free parameters of the ansatz to the Newton's equation of motion for a single degree of freedom (in a certain effective potential). At any value of the pulse's NOQ, the latter equation admits a single equilibrium position which corresponds to a stable stationary pulse. However, there is a definite threshold value of the NOQ such that above the threshold any initial configuration gets trapped into a stable pulse, while below the threshold the trapping takes place provided that the initial configuration is not too narrow, otherwise it will be spreading out indefinitely.

**THE 2D DIRAC EQUATION AND THE DAVEY-STEWARTSON I EQUATION: DE-
FORMATION OF THE DROMION SOLUTIONS (POSTER)**

Manuel Manáš

The 2D Dirac equation and a deformation of heat equation type of it in the group of invertible linear operators, when subject to adequate constraints, are shown to give solutions of the two-component Kadomtsev-Petviashvili equation, and in particular the Davey-Stewartson I equation. A one-parameter (the mass in the Dirac equation) family of solutions of the Davey-Stewartson I equation is studied in detail. This family contains the 1-dromion solutions and might be considered as a continuous deformation of it, being the Dirac mass the deformation parameter. It contains a special 2-line soliton solution as well. Once the comoving frame is chosen, in general –not for 1-dromion and the 2-line soliton– the solution has a breather character for the modulus of the amplitude.

**BREATHERS IN HAMILTONIAN LATTICES: STUDIES BASED ON THE ANTI-
INTEGRABILITY CONCEPT. (POSTER)**

José L. Marín (Universidad de Zaragoza, Spain) **Serge Aubry** (Laboratoire Léon Brillouin, CE Saclay, France)

We have performed numerical calculations of intrinsic localized modes ("breathers") in several classes of hamiltonian lattices with on-site nonlinear potentials, guided by the concept of *anti-integrability*. One of the main achievements has been the development of a powerful and robust method that not only yields accurate breathers but also elucidates the domain of existence of these periodic solutions in terms of the level of discreteness of the lattice and the breather frequency ω_b . This study should also help to understand the interesting subject of the connection between static and moving breathers.

The second achievement is the completion of the linear stability analysis of the periodic, static breather (Floquet-Krein analysis), something that can only be done with the accurate solutions obtained with the method developed. Such analysis uncovered a type of instability which was not expected: an "internal dynamics" instability, in which the breather undergoes a subharmonic instability that destroys its periodicity but not the spatial localization, thus yielding a QP

breather. We are currently working on an extension of Krein theory which should help to understand this kind of results under a much more general picture.

ON THE INTEGRABILITY OF A NEW CLASS OF WATER WAVE EQUATIONS (POSTER)

V. Marinakis & T.C. Bountis (University of Patras, Greece)

We examine two nonlinear partial differential equations (PDEs) from the point of view of their integrability. The first one is integrable and can be derived from the second through a local transformation recently introduced by Fokas. Reductions of the first equation of the form $u = u(x)$ or $u = u(x - t)$ are proved analytically (Painlevé analysis) and numerically (ATOMFT algorithm) to be integrable.

Moreover, the Painlevé analysis of the first PDE leads to a truncated expansion from which the Lax Pair can be obtained. We then make the reduction $n = n(x)$ for the second PDE and examine the ordinary differential equation (ODE) that we obtain. The Painlevé analysis identifies new integrable cases for this ODE and also gives – together with a numerical study of its solutions in the complex x -plane – strong indications that, in general, this ODE and therefore the second PDE from which it is obtained is not integrable.

MODULATIONAL INSTABILITY IN DISCRETE SYSTEMS (POSTER)

P. Marquie, J.M. Bilbaut, S. Dos Santos & B. Michaux (Université de Bourgogne, France)

We present two systems where the dynamics of modulated waves can be modeled by a generalized discrete nonlinear Schrödinger equation. The first one is a real discrete electrical lattice, where the generation of nonlinear localized modes is investigated. It is also shown that unlike envelope solitons which can be observed close to the zero dispersion point, the localized modes experience strong lattice effects. Next, we focus on energy localisation via modulational instability in a particular nonlinear molecular model, i.e. a cyclic molecule.

STATIC FLUXONS ON PERIODIC STRUCTURES (POSTER)

N. Martucciello (Università di Salerno, Italy) & **R. Monaco** (Istituto di Cibernetica del C.N.R., Arci Felice (NA), Italy)

A Josephson tunnel junction is certainly one of the most convenient solid-state device for the study of the non-linear phenomena and, in particular, for the investigation of the soliton properties. Further, the soliton (or fluxon) motion is smoother in annular, i.e. ring-shaped junctions since the collision of the fluxon with the boundaries are absent. For a long annular junction it is found that the partial differential equation which describes the evolution of quantum mechanical phase difference across the barrier ϕ is (in normalized units):

$$\phi_{xx} - \phi_{tt} - \sin \phi = \gamma + \eta \Delta \sin kx + \alpha \phi_t - \beta \phi_{xxt},$$

where γ is the distributed bias current normalized to the maximum Josephson critical current, η is the normalized externally applied field and α and β are

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where γ is the distributed bias current normalized to the maximum Josephson critical current, η is the normalized externally applied field and α and β are

adiimensional loss coefficients. Defining the dimensionless wavenumber $k = \frac{2\pi}{l}$ in which l is the normalized ring mean circumference, the quantity Δ is a factor, depending the geometrical configuration, which represents the coupling between the external field and the flux density of the junction. The periodic conditions, which derive from the fluxoid quantization, are:

$$\phi(x+l) = \phi(x) + 2\pi n \quad \text{and} \quad \phi_x(x+l) = \phi_x(x),$$

n being an integer number corresponding to the algebraic sum of fluxons trapped in the junction at the time of the normal-to-superconducting transition. Once trapped the fluxons can never disappear and only fluxon-antifluxon pairs can be nucleated. We have investigated the static configurations of the phase inside an annular Josephson tunnel junction in the presence of an externally applied magnetic field. Numerical integration of the static equation

$$\phi_{xx} - \sin \phi = \gamma + \eta \Delta \sin kx$$

reveals that the magnetic field generates a periodic potential for the static fluxons in the periodic structure; further, for a given applied field, a number of different phase profiles may exist which differ according to the number of fluxon-antifluxon pairs present in the structure.

CYCLOIDAL TRAJECTORIES OF VORTICES IN THE 2-D ANISOTROPIC HEISENBERG MODEL

F.G. Mertens, H.J. Schnitzer (University of Bayreuth, Germany) & **A.R. Bishop** (Los Alamos National Laboratory, USA)

For weak anisotropy there are "out-of-plane vortices" which exhibit a localized structure of the spin components perpendicular to the plane. The vortex equation of motion is 1st order and contains a velocity-dependent "gyrotropic" force (Thiele 1973). We generalize this by allowing changes of the vortex shape due to accelerations and derive a 3rd order equation of motion. It predicts a beat oscillation around the mean vortex path obtained from Thiele's equation. The two frequencies of the beat can be identified with the dominant doublet of the spectrum which we observe in computer simulations. Additional, much weaker doublets can be explained by 5th, 7th, ... order equations. More generally, we show that the equations of motion for "gyrotropic excitations" form a hierarchy of odd-order equations, while the equations for non-gyrotropic excitations (e.g. kinks or planar vortices) are of even order.

ISSUES RELATING TO THE ARREST OF CRITICAL COLLAPSE OF FEMTOSECOND PULSES IN NORMALLY DISPERSIVE SELF-FOCUSING MEDIA

Jerry Moloney (Tucson, USA)

Femtosecond optical light pulses offer a unique opportunity to explore the physical manifestations of 2D and 3D collapse phenomena in transparent nonlinear

optical media. We will report on the mechanism of arrest of critical collapse due to normal group velocity dispersion and plasma shielding, resulting from laser induced breakdown. The latter arises from avalanche processes for picosecond duration optical pulses and multiphoton ionisation for femtosecond duration pulses. Primary results from a 3D + time vector Maxwell numerical solution in the vicinity of the critical self-focus will be discussed.

TRAVELLING WAVES ON LATTICES

Bryce McLeod (Pittsburgh/Heriot-Watt)

The lecture concerns a method of discussing the existence and behaviour of travelling waves on lattices (a problem going back to Fermi, Pasta and Ulam) by creating a homotopy between different problems.

TRANSDUCTION OF ACOUSTIC WAVE ENERGY TO AN ELECTRO-CHEMICAL EVENT:

COCHLEAR PROBLEMS

Lionel Nautrin (Univ. of Glasgow, UK)

The anatomy of the mammalian hearing apparatus will be described, followed by details of the microanatomy of the cochlea. Indications will be given of the actual size of the structures involved. The generally accepted theory of transmission and transduction of the acoustic signal will be recounted; then observational and experimental data providing difficulties in accepting current teaching will be explained. An alternative explanation will be offered in brief outline and areas where mathematical contributions to the understanding of wave motion and energy will be suggested.

DYNAMIC FORM FACTORS IN THE TODA CHAIN

Andreas Neuper & Franz G. Mertens (Universität Bayreuth, Germany)

We investigate the correlation functions of the periodic Toda chain at finite temperature numerically by using a combination of Monte-Carlo and molecular-dynamics methods. Intermediate steps allow comparison to known analytical results, e.g. excitation spectra. We also show an analytic approach to the force-force-correlation functions of the Toda chain extending an idea of the soliton gas theory: Non-interacting cnoidal waves describe excited waves of all kinds, from harmonic to solitary behaviour. The obtained shape of the force-force structure factor for a fixed wavenumber is a smooth, asymmetric *single* peak with a steep high-frequency side. Numerical and analytical results are in good agreement.

[1] A. Neuper and F. G. Mertens, *Dynamic form factor for the Yomosa model for the energy transport in proteins*. In M. Peyrard, editor, *Nonlinear Excitations in Biomolecules*, Springer (Les Editions de Physique), p.286 (1995)

SOLITARY ION ACOUSTIC WAVES IN A PLASMA WITH NEGATIVE IONS AND NON-ISOTHERMAL ELECTRONS (POSTER)

E. John Parkes (Strathclyde Univ., Glasgow, UK)

The Sagdeev potential formalism is used to investigate the propagation character-

teristics of a finite amplitude compressional solitary ion-acoustic wave in a collisionless plasma comprising cold positive and negative ions and non-isothermal electrons. Attention is focused mainly on the effects of the degree of non-isothermality.

For strong non-isothermality and to lowest order, small amplitude waves have a $sech^4$ form. Higher order corrections to this are obtained via the Sagdeev potential rather than using the more usual method of reductive perturbation with renormalization. Existing results in the literature derived using the latter approach are corrected and extended.

Two-DIMENSIONAL SOLITARY WAVES IN ARRAYS OF NONLINEAR WAVEGUIDES

Thomas Peschel & F. Lederer (Jena)

Using both a variational and a fully numerical approach we derive solutions to the two-dimensional Discrete Nonlinear Schrödinger Equation which describes stationary optical beams in two-dimensional arrays of nonlinear waveguides. We compare our results to the respective solutions for the time-dependent case in a one-dimensional DNLS, which in contrast to the above fully discrete one represents a mixed discrete-continuous system. Possibilities for moving solitary waves are discussed on the basis of the Hamiltonian of the systems.

COLLISIONS OF SOLITARY WAVES DUE TO SECOND ORDER NONLINEARITIES (POSTER)

U. Peschel, C. Etrich & F. Lederer (FSU Jena, Germany) B. Malomed (University of Tel Aviv, Israel)

The investigation of solitary waves due to cascading has become one of the most interesting topics of nonlinear optics. Unfortunately the resulting system of two complex nonlinear equations seems do be not integrable. In the limit of infinite phase mismatch or pulse width the equations can be reduced to the NLS which is integrable and where solitons are known. But this special limit corresponds to diverging pulse energies required. Therefore a detailed analysis of the initial equations is unavoidable. It is known that in the stationary limit the equations have some bright solitary wave solutions, which have to be determined numerically except of one where an analytical form is known. Some of those solutions are stable during propagation some are not. We study the propagation and fusion of those spatial solitary waves in a quadratic nonlinear medium numerically. If we neglect the so-called walk off we can make use of the Galilean invariance of the resulting equations and can construct moving solutions from stationary ones. This method seems to be the best to test whether the solitary waves found are true solitons. We find that if the solitary waves collide with a high relative velocity they penetrate each other and therefore behave like real solutions. If one undergoes a critical velocity both solitary waves merge and form a new stable but oscillating state while some energy is lost by radiation. Even near the Schrödinger limit (big phase mismatch) the collision behaviour differs from that found for

the solitons of the NLS. Further the final state critically depends on the phase difference between the initial solitary waves. Phase differences generally reduce the probability of a fusion but may cause some energy exchange between the different solitary waves.

THE SINGULAR MANIFOLD METHOD REVISITED

Andrew Pickering (Vrije Universiteit Brussel, Belgium)

For many completely integrable partial differential equations (PDEs) it is possible to recover the Lax pair and Darboux transformation from a truncated Weiss-Tabor-Carnevale (WTC) Painlevé expansion. The constraint on the movable singular manifold for such truncation to exist is usually referred to as the “singular manifold equation.”

However for some completely integrable PDEs the above procedure does not work. We show that for PDEs such as modified Korteweg-de Vries or Broer-Kaup the required generalisation is one which corresponds to summing an infinite WTC expansion for certain choices of arbitrary data. This is a natural extension of the usual truncation process, and of course involves only one singular manifold. We then give a new and more consistent definition of “singular manifold equation.”

The summation of an infinite WTC expansion is achieved by seeking a truncation in a function Z which satisfies a system of Riccati equations. This approach also allows us to place within the context of Painlevé analysis a larger class of exact solutions than was possible hitherto.

FREQUENCY STABILITY ENHANCEMENT MEASURED IN A SOLITON-LOCKED TYPE REGIME OF A SURFACE ACOUSTIC WAVE DELAY LINE OSCILLATOR

M. Planat, Franck Lardet-Venard, G. Martin & M. Hourtin (LPMO-CNRS, Besançon, France)

An injection-locked low frequency regime is established in a surface acoustic wave quartz delay line oscillator by using modulating techniques and nonlinear envelope detection. Frequency-Temperature plots shows soliton-locked type regimes with considerably enhanced frequency stability (the enhancement is at least six orders of magnitude in comparison to the unlocked one). The underlying determinism is found to arise from a resonance between the carrier frequency and that of the envelope. From the nonlinear Schrödinger model stable steps attached to the frequency -amplitude characteristic are expected in agreement with the experiment. In addition a fine structure with repulsive levels is observed. Sub-harmonics are found in three types of frequency ratios: Farey type levels ($1/2$, then $1/3, 2/3, \dots$), Jain type levels at $p/(2p+1)$, with p integer and non rational Markov type levels ($((\sqrt{5}-1)/2, \sqrt{5}(2-1), \dots)$). A topological explanation using hyperbolic spaces for those structures is attempted.

ON A SHALLOW WATER WAVE SYSTEM (POSTER)

T. J. Priestley (University of Exeter, UK)

In this poster we discuss symmetry reductions for the shallow water wave system

$$\begin{aligned} u_{xxt} + \alpha u u_t + \beta v u_x - u_t - u_x &= 0, \\ v_x &= u_t, \end{aligned} \quad (1)$$

where α and β are arbitrary, non-zero, constants. This arises as a scalar equation in non-local form by setting $v = \hat{\partial}_x^{-1} u_t$ where $(\hat{\partial}_x^{-1} f)(x) = \int_x^\infty f(y) dy$, using the so-called Boussinesq approximation, but has also been discussed in local form obtained by setting $u = U_x, v = U_t$. Two special cases of these scalar equations have been discussed in the literature, namely $\alpha = \beta$ and $\alpha = 2\beta$. The inverse scattering problem has been solved in both cases, as have both cases been studied using Hirota's bi-linear technique. A full catalogue of classical and nonclassical reductions have been given for the general local scalar equation.

We seek symmetry reductions of (1) using the classical Lie method of infinitesimal transformations, the nonclassical method due to Bluman & Cole and the direct method due to Clarkson & Kruskal. In particular, we show that the nonclassical and direct methods yield different reductions. Not only are they different but, unlike for scalar equations, we are able to find reductions using the direct method which cannot be found using the nonclassical method.

DYNAMICAL R-MATRIX FOR A NEW INTEGRABLE SYSTEM RELATED TO "PEAKONS"

Orlando Ragnisco (University of Rome III, Italy)

A dynamical system modelling the mutual interaction of the so-called "peakons" of the Camassa-Holm equation is considered. The system has been recently proved to be endowed with a Lax pair and to be completely integrable by F.Calogero and J.P.Francoise. Here, the complete integrability is demonstrated in the framework of the R-matrix approach. In a special case, the system reveals an intimate connection with the Toda lattice : inspired by that, we have been able to factorize the Lax matrix and to construct an auto-Backlund transformation or, in other words, an integrable time-discretisation of the system.

NON-LOCAL NONLINEAR SCHRÖDINGER EQUATION (POSTER)

Kim O. Rasmussen (DTU, Lyngby, Denmark)

A non-local nonlinear Schrödinger equation is introduced and studied. Stationary solutions of this equation are obtained and discussed. It is found that the stationary solutions of the usual nonlinear Schrödinger equation are significantly modified by long range effects. Furthermore, we find a collapse like effect in the one dimensional cubic nonlinear Schrödinger equation when long range effects are included.

MODULATIONAL INSTABILITY IN REAL SYSTEMS

M. Remoissenet, J.M. Bilbaut, P. Marquie, B. Michaut, G. Millot & E. Seve (Bourgogne, France)

The problem of observation of Benjamin-Feir or modulational instability of colinear waves in real one-dimensional systems is reviewed. It is illustrated by laboratory experiments on deep water waves, waves in electrical transmission lines and in optical birefringent fibers which, show the limit of the nonlinear Schrödinger model.

EVIDENCE FOR ENERGETIC LATTICE EXCITATIONS AND PRACTICAL APPLICATIONS

F.M. Russell (CLRC, Rutherford Appleton Lab, UK)

A new energy loss process for energetic atomic particles passing through matter has been discovered. Studies of this new process in the mineral mica have shown that the energy lost by the particles is coupled to the lattice to create a type of lattice excitation not previously reported. These lattice excitations can propagate great distances in mica without degradation and in many ways resemble breather solitons. From these studies it was predicted that in-elastic scattering of these solitons from a crystal surface should produce observable effects and this is confirmed by experiment. It has been shown that the energy in these solitons can exceed 100eV and so they will be important in both chemical and physical processes in the solid-state. Some implications and applications of these energetic solitons are considered.

BASIS FUNCTIONS FOR STRONGLY CORRELATED FERMI SYSTEMS

Mario Salerno (University of Salerno, Italy)

A general method to construct basis functions for fermionic systems which account for the $SU(2)$ symmetry and for the translational invariance of the Hamiltonian is presented. The method does not depend on the dimensionality of the system as well as on the symmetry of the lattice. As an example we present the block diagonalization of the Hubbard hamiltonian for finite number of sites in one and two dimensions.

HOW TO PREDICT, TO GENERATE AND TO OBSERVE STRAIN SOLITONS IN SOLIDS

Alexander M. Samsomov (A.F.Ioffe Physical Technical Institute of the Russian Academy of Sciences, St.Petersburg, Russia)

An approach is proposed in order to solve the problem mentioned above. The nonlinear elastic guided wave propagation problem is known to reduce to the quasi hyperbolic 1+1D nonlinear double dispersion equation, written with respect to the longitudinal strain u as

$$u_{tt} - c_0^2 u_{xx} = (1/2) (c_2 u^2 + \nu^2 R^2 (u u - c_1^2 u_{xx}))_{xx} \quad (1)$$

where the wave guide is assumed to be a circular rod of radius R , and ν, c_0^2, c_2 , c_1^2 are the Poisson coefficient, the nonlinearity parameter, the linear longitudinal and shear wave velocities, resp.

The solitary wave solution of (1) was found to be a bell-shaped pulse having an amplitude A , a length λ and a velocity V :

$$u_1 = A \cosh^{-2}[(x \pm Vt)/\lambda] = [3(V^2 - c_0^2)/c_2] \cosh^{-2}(x \pm Vt) \left[\nu R \sqrt{\frac{2(V^2 - c_1^2)}{V^2 - c_0^2}} \right]^{-1} \quad (2)$$

or the similar wave $u_2 = u_0 + A \cosh^{-2}[(x \pm Vt)/\lambda]$ having a pedestal u_0 :

$$u_2 = 2[(V^2 - c_0^2)/c_2] - [3(V^2 - c_0^2)/c_2] \cosh^{-2} \left\{ (x \pm Vt) \left[\nu R \sqrt{\frac{2(V^2 - c_1^2)}{V^2 - c_0^2}} \right]^{-1} \right\} \quad (3)$$

Parameters of both nonlinearly elastic material and the initial weak shock wave were estimated in order to generate the longitudinal strain soliton in a rod. It was found that both sets of parameters must satisfy several compatibility conditions, in particular, for waves (2) and (3) there is the so-called 'dead zone' of velocities, in which no bell solitons can be generated. Plastic flow of deforming material must be avoided also.

The experiments on strain solitary wave observation are based on the optical holography methods. After the interferograms reconstruction it was found that the wave meets all main features of a soliton.

TOPOLOGICAL SOLITON SUPERSONIC STATES

A.V. Savin (Moscow)

Topological soliton supersonic states in the bistable molecular chain with a cubic anharmonic intersite interaction have numerically been studied. The positive topological soliton (kink) in a symmetric bistable phi-4 system has subsonic continuum and discrete supersonic velocity spectrums. The kink has only finite number of supersonic velocity values. The soliton moves without phonon radiation only for these values. The number of supersonic velocity values increases when the anharmonicity becomes stronger. Each supersonic kink represents a few of acoustic soliton bound states. The amplitude sum of these acoustic solitons equals the barrier width of the phi-4 potential.

A COLLECTIVE-VARIABLE THEORY FOR GYROTROPICAL EXCITATIONS IN HAMILTONIAN SYSTEMS

H.J. Schnitzer, F.G. Mertens (University of Bayreuth, Germany)

One familiar method to incorporate collective variables in Hamiltonian systems is to transform the original phase space variables (\vec{Q}, \vec{P}) to a larger and therefore constrained set of variables $(\vec{q}, \vec{p}, \vec{X}, \vec{Y})$, where \vec{q} and \vec{p} denote small fluctuations

and \vec{X} and \vec{Y} the collective position and momentum variables, respectively. I.e. collective coordinates are introduced as additional variables. This is different from the standard approach where the number of variables is much reduced by retaining only collective variables. We use the above method to derive a collective-variable theory for so-called 'gyrotropical excitations' (we will define this term in our talk, examples are certain types of vortices in 2D-systems like the anisotropic Heisenberg model, superfluid He-films, ...). As one important result we obtain equations of motion showing that no momentum and therefore no mass can be defined for these kind of collective excitations.

FLUX INTERACTIONS ON STACKED JOSEPHSON JUNCTIONS

Alwyn Scott (DTU, Lyngby, Denmark)

Perturbation methods are used to study the dynamics of locked fluxon modes on stacked Josephson junctions and single crystals of certain high-Tc superconductors. Two limiting cases are considered: (i) The non-linear diffusion regime in which fluxon dynamics are dominated by energy exchange between the bias and loss parameters, and (ii) The propagating regime in which the interplay between magnetic and electric field energies governs the fluxon dynamics. Conditions for stability of locked fluxon modes are shown to be different in these two regimes.

COUPLED COHERENT NONLINEAR OPTICAL SYSTEMS (POSTER)

Iain Skinner (University of New South Wales, Australia)

The physics behind coupling in coherent nonlinear optical structures used as all-optical switches is briefly reviewed, and the assumptions made in modelling these with coupled Duffing equations are outlined. Extending these to the assumptions pertaining to pulse propagation produces an assortment of coupled nonlinear Schrödinger equations. Results are described for some examples: cw switching with a $LP_{01} \leftrightarrow LP_{02}$ mode-converting grating; pulse switching with periodic & tri-cored directional couplers.

A LATTICE GREEN'S FUNCTION THEORY AND A BAND-THEORETIC CONCEPT OF NONLINEAR LOCALIZED MODES IN NONLINEAR LATTICES

Shozo Takeo (Gumma University, Kiryu, Japan)

A theory of nonlinear localized modes in nonlinear lattices using a lattice Green's function method is developed with particular attention paid to treating one- and higher-dimensional cases on equal footing. The theory is formulated for d-dimensional hypercubic lattices with nearest neighbor interactions for which explicit expressions for d-dimensional lattice Green's functions are available and concrete results are obtainable, within the framework of the rotating-wave approximation (RWA), for the properties (interplaying among the nonlinearity, the lattice discreteness and the space-dimensionality of lattice systems, in particular) of stationary (non-moving) nonlinear localized modes. Improving the RWA is straightforward.

Results obtained are summarized as follows: (1) A band-theoretic concept holds for stationary nonlinear localized modes in nonlinear lattices. Namely, stationary nonlinear localized modes can be interpreted as those eigenstates which are separated from the top, the bottom, or the both (duality) side of, the frequency or energy band of the corresponding linear lattices by the intrinsic nonlinearity of the systems. (2) This gives us a hint on how to get approximate analytical results for moving nonlinear localized modes. (3) The concept appears general, suggesting the ubiquity of the existence of stationary nonlinear localized modes. (4) Except for possible existence of a critical value for the strength of nonlinearity, no basic difference exists between one- and higher dimensional cases for the appearance of the stationary nonlinear localized modes. This suggests that in discrete lattices, no collapsing of stationary nonlinear modes exists. (5) Concrete results, both analytical and numerical, are given on the properties of intrinsically discrete nonlinear modes: (a) nonlinear localized modes in simple-cubic lattices ($d = 3$) (b) strongly localized modes in the diatomic Toda lattice and (c) duality of the existence, for a given nonlinearity, of stationary nonlinear localized modes in sine-lattices.

A poster will also be presented on a very recent result obtained in collaboration with M. Peyrard on a new kind of nonlinear localized modes, nonlinear rotating modes, in coupled rotator systems (sine-lattices) exhibiting very strong localization and possessing intrinsically discrete character.

A NEW TYPE OF TOPOLOGICAL LOCALIZED MODE: THE ROTATING MODE (POSTER)

Shozo Takeno & Michel Peyrard (Gunma University, Kiryu, Japan & Ecole Normale Supérieure de Lyon, France)

The sine-lattice models derive from an hamiltonian where both the coupling potential and the on-site potential are periodic functions with multiple degenerate minima. This allows the existence of a new class of localized topological excitations, the rotating modes, which share however some properties on the non topological oscillatory modes. An approximate analytical solution is obtained. Numerical simulations show that an exact solution is likely to exist and that the rotating modes are stable against collisions with breathers and can be thermally generated. Due to their structure, these modes which exist for any value of the coupling, strong or weak, are intrinsically discrete. Some consequences for physics are discussed.

KINK LIKE SOLITON PROPAGATION IN MICROTUBULE PROTOFILAMENTS (POSTER)

Beata Trpisova (University of Alberta, Edmonton, Canada)

The subject of my work are microtubules (MT). MTs are biological structures that are an important part of the cytoskeleton of eukaryotic cells. They participate in cell division, information transfer and transport of materials within the cell, they play a role in changing the shape of the cell and other important cell

activities.

MTs are assembled from the molecules of tubulin that have dipole character. Tubulin molecules form protofilaments along the axis of the tubule. In the process of the assembly i.e. attaching a molecule of tubulin to a MT the energy of about 0.43 eV is released through the hydrolysis of GTP into GDP. Our aim is to find what happens to this energy in a biological, hence very efficient system. We conjecture that the energy can be used in the disassembly of the MTs, attaching of microtubule associated proteins (MAPs) or it can be utilized in some other yet unknown way. In my work I used a model proposed by my supervisor Dr. Tuzynski. In this model a MT protofilament is described as 1-D chain of ordered dipoles that are coupled with elastic forces (polarization and dislocation are coupled linearly). In the continuum approximation the model has an analytical solution a kink like soliton traveling at a constant velocity that is proportional to the electric field produced by the MT when it is in its completely ordered state (ferroelectric). This implies that applying an external electric field to a MT in parallel or opposite direction to the intrinsic MT electric field can result into a faster or slower kink. The kink is a domain wall between two subchains of dipoles oriented in the opposite direction. The effect of MAPs has been modeled numerically using the same model where an attached MAP was represented by a gaussian potential. The presence of the potential slows the kink down. When the amplitude of the potential reaches a critical value the motion of the kink is stopped completely. For the kinks with smaller velocities this critical value is smaller.

BREATHER-LIKE IMPURITY STATES AND OTHER PROPERTIES OF NONLINEAR LATTICES

Giorgos Tsirosis (University of Crete, Greece)

We will present recent work on localized modes in Ablowitz-Ladik like systems. We will discuss the possible physical significance of the model. We will also present stationary properties of a nonlinear Kronig-Penney model with delta-function and discuss applications in the context of nonlinear photonic band gap materials.

STABILITY OF OPTICAL SOLITONS

Sergei Turitsyn (Düsseldorf, Germany)

An overview of the recent results related to the problem of soliton stability and collapse in the nonlinear optics will be presented. I will introduce a concept of the $\text{je}m_2$ controlled collapse/ em_2 and discuss possible applications. Recent exact functions and discuss applications in the context of nonlinear photonic band gap materials.

MULTI-PERIODIC PROCESSES IN FUNCTIONAL EQUATIONS

J. A. Zagrodzinski (Polish Acad. of Sciences, Warsaw, Poland)

Applying the formalism of dispersion equations there are discussed the solutions of functional equations having a close affinity with KdV and SG equations. There are considered completely functional and semifunctional (system of odes) variants.

It appears that standard features relating to soliton-type pde are conserved in these cases also and one can obtain the multisoliton, multiphase quasi-periodic solutions and also the solutions in form of solitons on periodic background. Besides of a cognitive significance the existence of functional equations soliton-type solutions is important also from applicative point of view, since it makes a better approximation of numerical schemes for pde's.

J.A.Z. Phys.Rev.E, **51**, 2866, (1995).

NONLINEAR THEORY OF PARAMETRIC INSTABILITY IN DEFOCUSING MEDIA

Vladimir E. Zakharov

Parametric instability in continuous media is the exponential growth of wave pairs with opposite wave vectors (if the pumping is uniform in space). The standard nonlinear theory of the instability considers the most important interaction of pairs of the waves. This interaction leads to renormalization of the pumping and finally to saturation of the instability on a certain level proportional to the pumping intensity. The corresponding theory (S-theory) is developed in detail. The purpose of this talk is to show that in some cases S-theory describes only the intermediate asymptotics, and the final state is quite different. It can be demonstrated in the framework of a very simple model - the Nonlinear Schrödinger equation with defocusing nonlinearity and additional pumping and damping terms. In this case the final result of the instability is the formation of a "condensate" - a uniform oscillation of the medium. The final state is degenerate - the phase of the condensate can take two opposite values, and a final state can include a "kink" separating regions of different phases. It is remarkable that in the limit of very small pumping the level of the condensate remains finite - depending only on the frequency of the pumping. The model described can be applied to antierromagnets. A parametric pumping can be used for the generation of monochromatic signals of a very high intensity in nonlinear media of different kinds.

NONLINEAR PROTON DYNAMICS IN HYDROGEN-BONDED NETWORKS

Alexander V. Zolotaryuk (Kiev)

A 2D nonlinear lattice model has been suggested for studies of proton dynamics in ice-like networks. The model does not violate the fundamental Bernal-Fowler rules and therefore it adequately describes dichotomously branching transfers of protons in 2D and 3D hydrogen-bonded networks. Nonlinear collective excitations such as 2D topological kinks have been shown to describe positive and

negative ionic defects in ice. The dynamical process of creation of ionic defect pairs and the dependence of its density on temperature has been studied in the frame of this model. The soliton dynamics of the 2D topological defects is shown to differ essentially from the well-known soliton motion in 1D kink-bearing systems. Thus, the defects cannot propagate so freely as usual soliton-like quasi-particles because of the dichotomy of proton transfers in hydrogen bonds.

ENVELOPE SOLITONS IN A SYSTEM OF MAGNETIC PENDULUMS (POSTER)
Y. Zolotaryuk, J. C. Elbick (Henriot-Watt University), **T. Dauxois** (Ecole Normale Supérieure de Lyon, France) & **F.M. Russell** (CLRC, Rutherford Appleton Lab. & Heriot-Watt University, UK)
A model which represents an anharmonic chain of "magnetic pendulums" placed in the gravitational field is studied both analytically and numerically. The intersite coupling between pendulums is given by the interaction of the magnetic dipoles placed at the pendulum ends. We find experimental evidence of robust moving breathers-like modes, and the existence of these solutions is investigated analytically in the quasi-continuum limit. Their stability is demonstrated by the numerical simulations of the corresponding equations of motion.

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